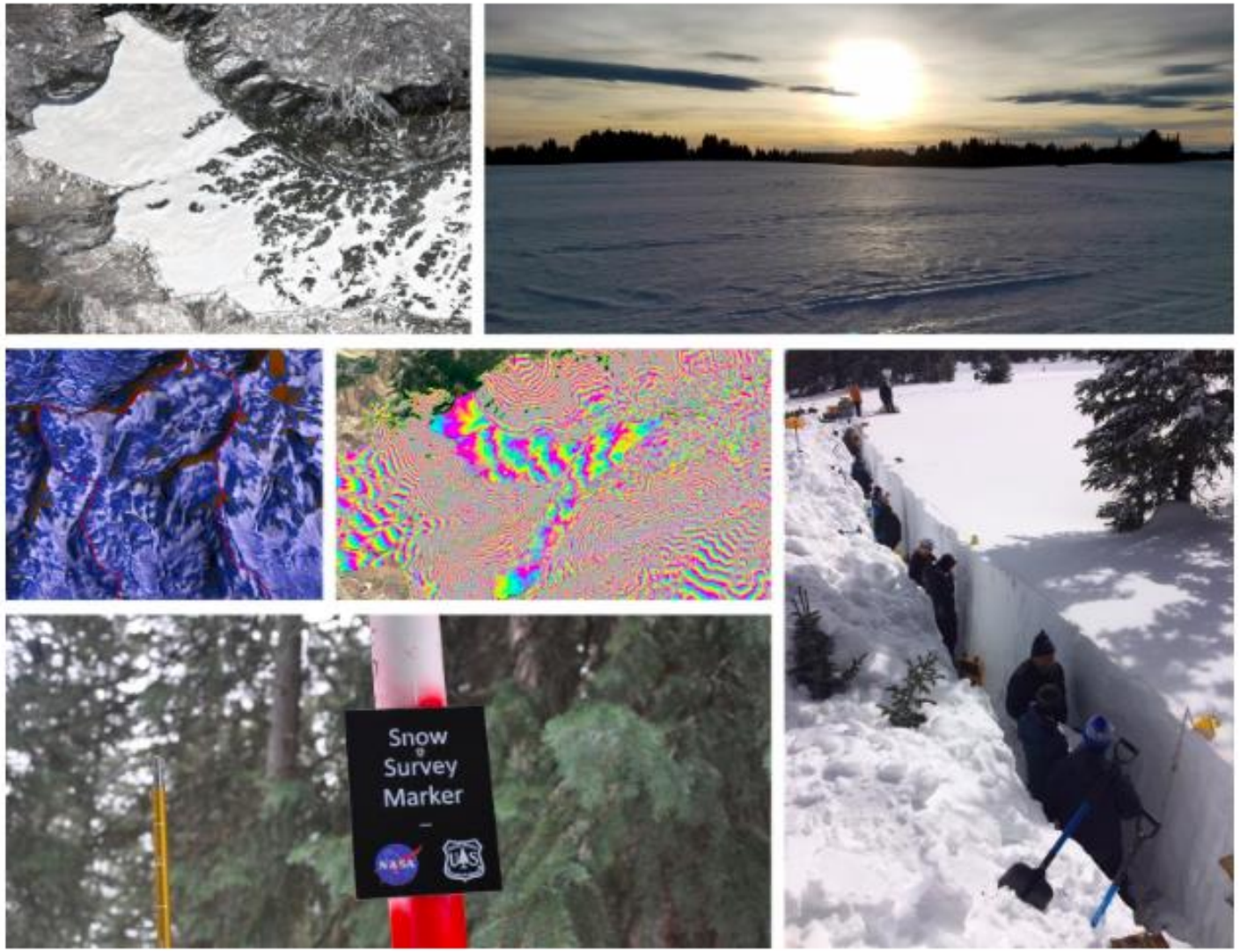
NASA SnowEx Science Plan:

Assessing Approaches for Measuring Water in Earth's Seasonal Snow



Presentation to iSWGR

November 5, 2018

Mark Raleigh and Mike Durand presenting for Science Plan Writing Group: Charles Gatebe, Ed Kim, Noah Molotch, Thomas H. Painter, Melody Sandells, and Carrie Vuyovich

Outline

- Summary and review
  - SnowEx Science Plan version 1.6
  - Community feedback from October 2018 survey

- Open discussion

What is SnowEx?

- Five year program funded by NASA THP to address the most important gaps (technology, science) in snow remote sensing

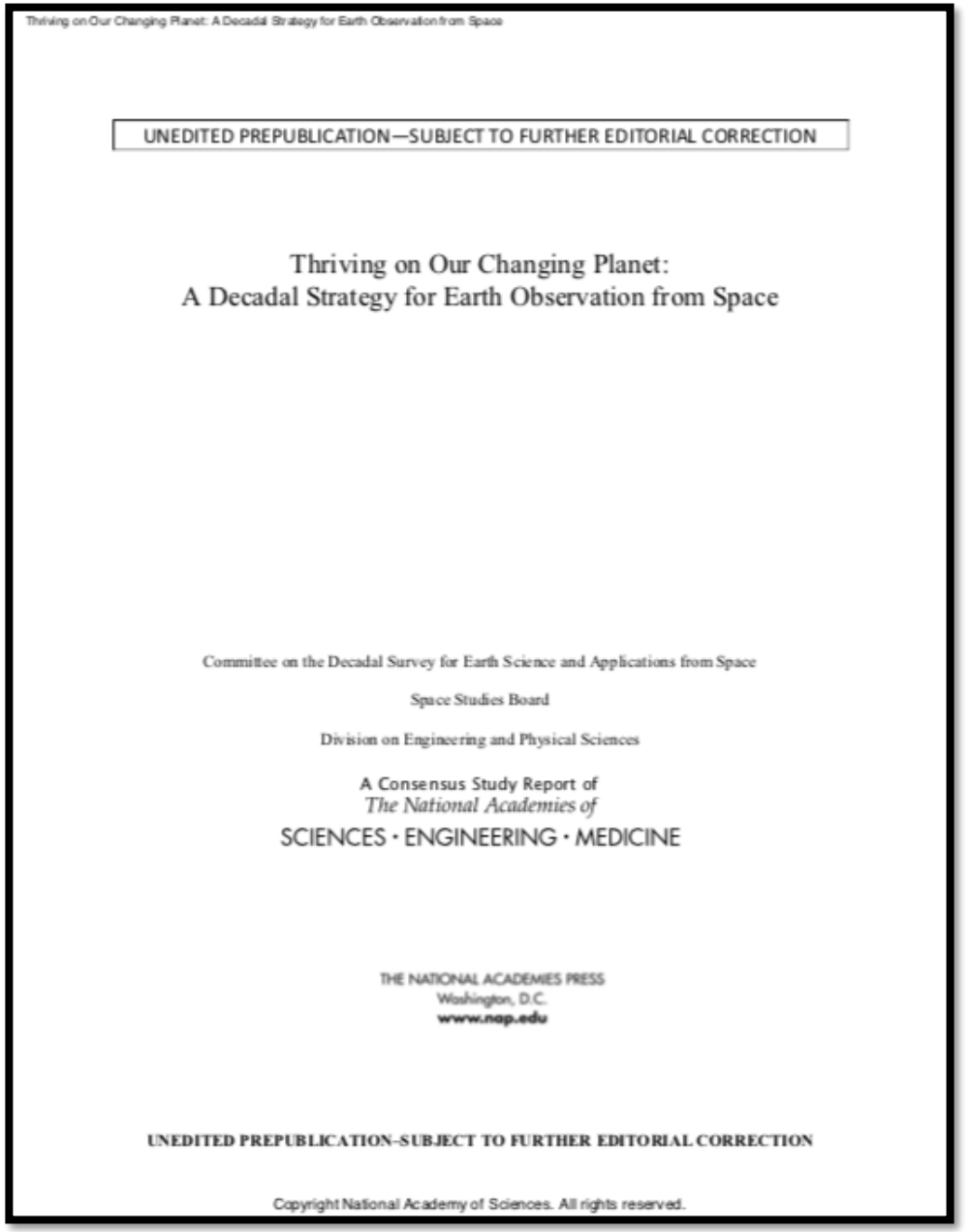
- **Goal**: Lay the groundwork for a future satellite mission with capabilities to measure snow globally (with focus on SWE)

- **Approach**: Coordinated airborne and ground field campaigns with a variety of measurement techniques and different environments

Why SnowEx? Why now?

- Well over a decade since last NASA-organized snow campaign
  - New capabilities in snow measurement, modeling, assimilation

- The 2018 National Academies Earth Science Decadal Survey included two snow-relevant recommendations:
  - A "**designated**" hyperspectral mission for measuring several targets, including snow cover, albedo (SBG)
  - An "**explorer**" mission for measuring snow depth / SWE <u>to be competed</u>


Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space

UNEDITED PREPUBLICATION—SUBJECT TO FURTHER EDITORIAL CORRECTION

Thriving on Our Changing Planet:
A Decadal Strategy for Earth Observation from Space

Committee on the Decadal Survey for Earth Science and Applications from Space

Space Studies Board

Division on Engineering and Physical Sciences

A Consensus Study Report of
The National Academies of
SCIENCES · ENGINEERING · MEDICINE

THE NATIONAL ACADEMIES PRESS
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UNEDITED PREPUBLICATION-SUBJECT TO FURTHER EDITORIAL CORRECTION

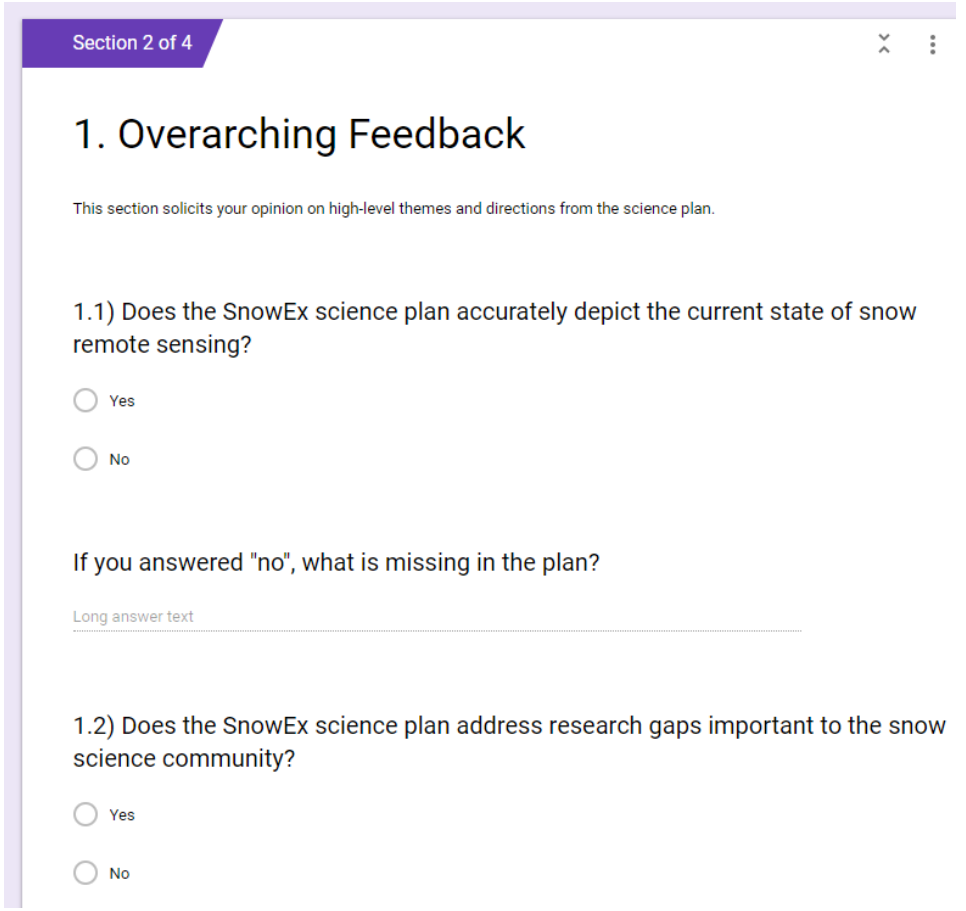
Timeline

- **January 2018**: National Academies unveiled the 2018 decadal survey
- **March 2018**: SnowEx Science Traceability Matrix developed for future years
- **June 2018**: NASA SnowEx Science Plan team begins drafting the plan
- **August 2018**: iSWGR presentation on Science Plan (v1.5) and first call for community feedback (informal via Google Docs)
- **October 2018**: Science Plan (v1.6) released to community and second call for community feedback (formal survey)

What was the community survey?

Note: still processing feedback received!

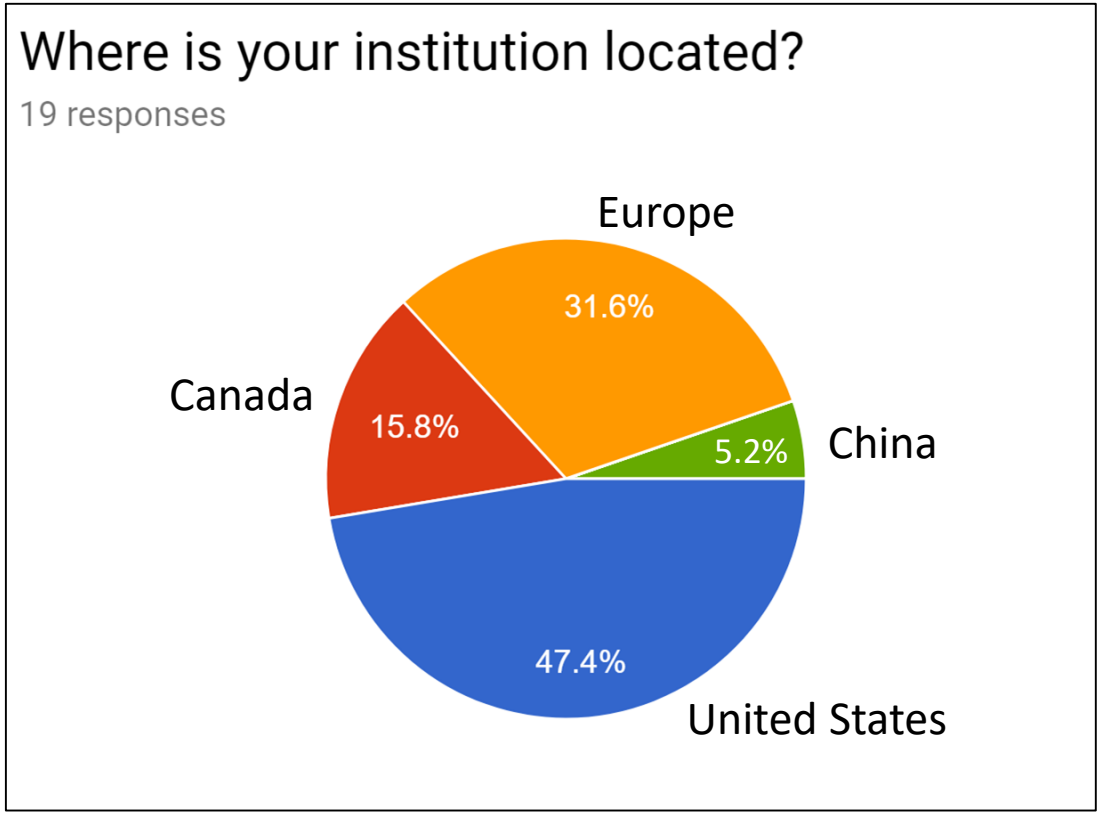
- Released science plan v1.6 in mid-October and requested community input via Google form survey
- Was open through November 2
- Three sections:
  - Overarching feedback
  - General feedback
  - Respondent info (only mandatory part)



Community survey: Who responded?

Note: still processing feedback received!

- 19 respondents
- Multi-national response
- 79% academics, 21% government
- Nearly even split in career stage:
  - 53% early career or student
  - 46% mid-senior career
- Snow interests most motivated by:
  - Hydrology
  - Remote sensing tech/science
  - Climate/weather
- Most “experts” from passive microwave, none from lidar



What is the SnowEx Science Plan?

- **Purpose**: Support decision making for future (i.e. 2020 and 2021) SnowEx campaigns. Provide guidance to implementation teams
- **Scope**: Set priorities; implementation left to implementation team
- **Format**: Charge was received from Jared Entin, THP program manager. Structured around articulating several “gaps”.
- **Focus**: Where are there opportunities to solve problems, better understand our measurements, models, algorithms etc., and push things forward? Note – clarify SWE, SCA, fractional snow cover
- **Audience**: everyone interested in SnowEx activities. Jared Entin, Jack Kaye, iSWGR, THP16, larger scientific community
- **Status:** This is a living document that seeks community input.

Major Elements of the Science Plan

- Review of technologies for measuring SWE and other snow cover characteristics (albedo, temperature, extent)
  - *Focus was on synthesis of methods – factors like cost still need consideration*
- Identification of “gaps”
- Recommended directions (locations and leveraged opportunities)
- Integrating remote sensing with models/assimilation

Other elements (not reviewed today): science questions and traceability matrix

Technologies: Science Plan

Tables were populated by consulting quad charts informed by community workshops, the literature, and discussions with experts.

Some subjectivity is admittedly present.

Table 1. Summary of snow depth/SWE and snow melt estimation techniques

		Snow Characteristic			Gap Capabilities							Space Potential		
Type	**Snow sensing/ estimation Technique**	**Snow Depth**	**SWE**	**Melt**	**High-Res**	**Wet snow**	**Deep Snow**	**Forests**	**Complex Terrain**	**Shallow Snow**	**Clouds**	**Path to Space**	**Global coverage**	**Mature Algorithm**
SWE via snow depth	Lidar													
	Ka-band InSAR													
	Dual band Ku/Ka													
	Stereo Photogrammetry													
	Wideband Radiometer													
volume scattering	Ku-band SAR													
	Passive Microwave													
signal interferom.	L-Band InSAR													
	Signals of Opportunity													
airborne / ground only	FMCW Radar													
	Gamma													

Green – Demonstrated capability. May not work in all areas, but uncertainty is understood. May still benefit from additional research and algorithm development. TRL > 5?

Yellow – Potential capability identified and validated in multiple studies. Research needed to better quantify uncertainty. TRL 3-5?

Orange – Potential capability identified, but uncertainty not quantified. High risk. TRL 1-2?

Red – No Capability

Technologies: Community Feedback

- 84%: the Science Plan depicts the current state of remote sensing

- Quotables:
  - “The evaluation of different sensor technologies as well as the proposed analysis in combination with ground observations should provide valuable information for assessing the trade-offs for the various pathways to a spaceborne mission.”
  - “it could be argued that some of the technologies have been more or less proven to be inadequate in terms of spaceborne remote sensing.”
  - “my feeling is, this needs to be short circuited, and the community needs to decide which star [technology] to hitch the wagon to…[rather than be] distracted by field campaigns”.

- Themes:
  - Microwave mentioned more than lidar altimetry in open responses
  - Albedo and snow cover mapping need more attention
    - Connectivity to SWE not always clear
    - Lack of detail about methods and recent advances/platforms (Sentinel, AVIRIS-NG)
    - May be too “optimistic” about mapping albedo

Science gaps proposed

- The final list includes:
  - Forest Snow
  - Maritime Snow
  - Mountain Snow
  - Prairie Snow
  - Snow Surface Energetics
  - Tundra Snow
  - Wet Snow
- We found explicit prioritization of these to be a challenge. We focused on clustering them, and seeing which might be addressed with SnowEx activities

Science gaps: Community Feedback

- 84%: the Science Plan addresses gaps important to the community

- Quotables:
  - “of course all snow-covered environments are relevant within the climate system so no[ne] should be left aside”

  - “I don't think the ‘least known’ necessarily requires ‘immediate attention’. Although it may come with uncertainties, I think what requires ‘immediate attention’ should be based on relevance for human societies and related ecosystems, and those may not be the least known.”

- Themes:
  - Echoed the importance of snow in (most-least common responses):
    - Mountains
    - Forests
    - Tundra
    - Maritime zone
  - We are missing snow over ice (frozen lakes, sea ice, glaciers) and focus on snow-on-land only

Science Plan: Recommend Directions

Organize annual campaigns to address one or more gaps:

2017: Forests
2019: Forests, mountains, wet snow ….

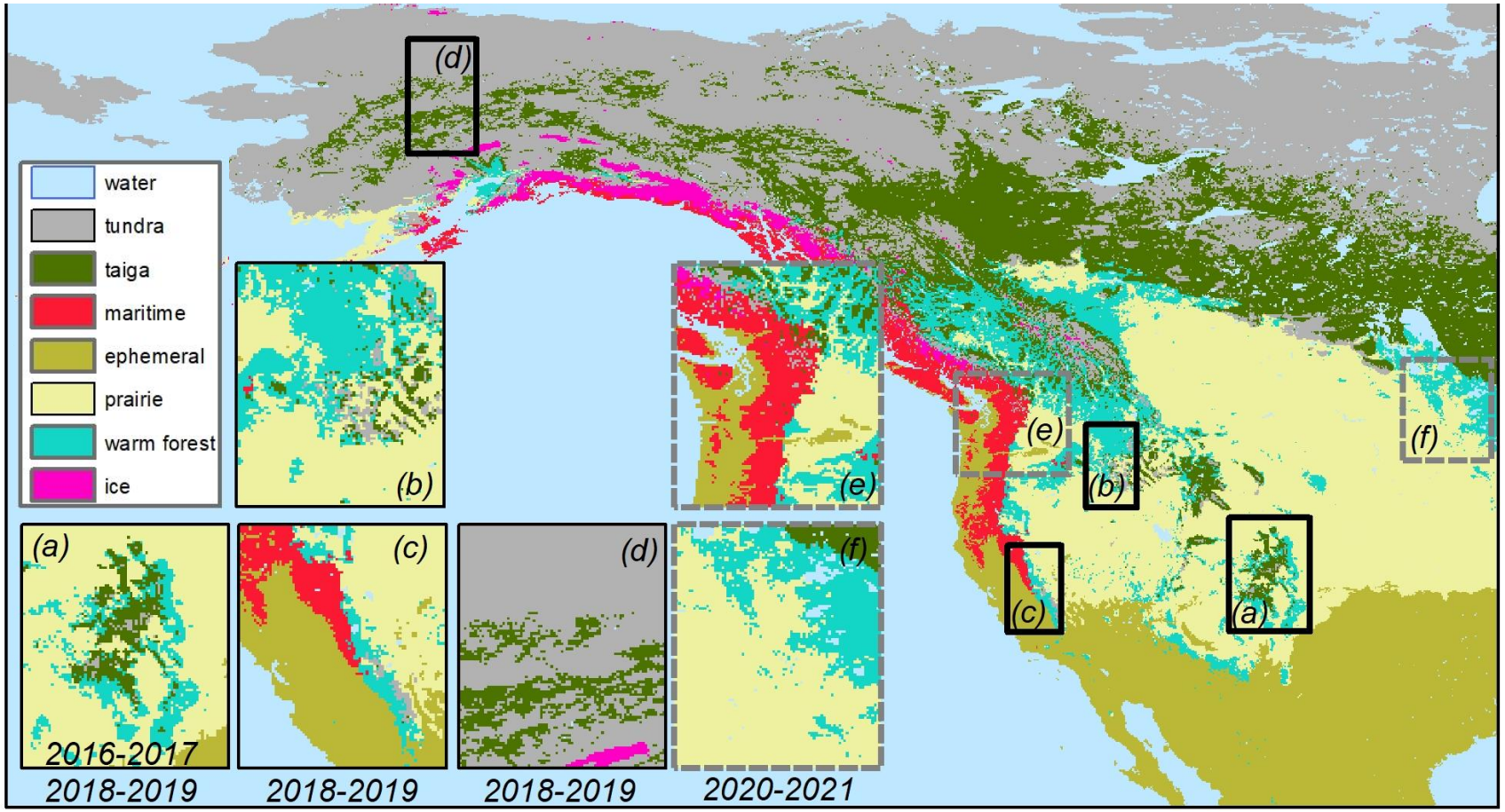
2020*: tundra, boreal
2021*: prairie and/or maritime

**proposed, not yet approved by NASA*

Leverage other community activities, for example:

- ASO in 2017, 2019
- ABoVE in 2020

Notional study domains and snow climates (Liston/Sturm classification)



SnowEx direction: Community Feedback

- 78%: executing the plan positions NASA SnowEx to put forward viable concept for future snow measurement mission

- 78% understand the proposed direction of SnowEx

- Quotables:
  - “It seems generally sound given the defined scope, but I would work to ensure that consistent error/accuracy metrics be reported for each type of remote sensing measurement to facilitate apples-for-apples comparisons.”

  - “SnowEx 2020 will be a big step in understanding snow dynamics in boreal forests, where there have been limited (or no) lidar flights. And if SnowEx 2021 goes to the Pacific Northwest, this will generate a comprehensive dataset allowing comparisons of all forest snow environments. “

- Themes:
  - Need more connectivity to atmospheric science community and forecasting

Modeling/assimilation: Community Feedback

- Quotables:
  - “It is critical to improve the observation capability of seasonal snow, using observation methods that *make it possible to be used in combination with in-situ and model approaches*. Satellite-only based methods are very likely to fail, and it is great that this fundamental flaw in CoReH2O design is not repeated here.”

- Themes:
  - Community valued multi-sensor approach w/ models & assimilation
  - Need more detailed description of model systems and assimilation and how they should support remote sensing data
    - e.g., snow density, snow microstructure
  - More attention to the resolution of models and remote sensing

Next steps for science plan:

- Revise science plan based on community survey, discussions

- Have more comments? Please contact:
  - Mike Durand (Durand.8@osu.edu)
  - Mark Raleigh (mark.raleigh@colorado.edu)

- Present update/next version at AGU SnowEx Town Hall (Thursday)

Open discussion: some questions to ponder

- Where does the snow remote sensing community go from here?
- What is the optimal progression for down-selecting the various SWE mapping approaches in the road ahead?
- What are we doing right? What are we missing?